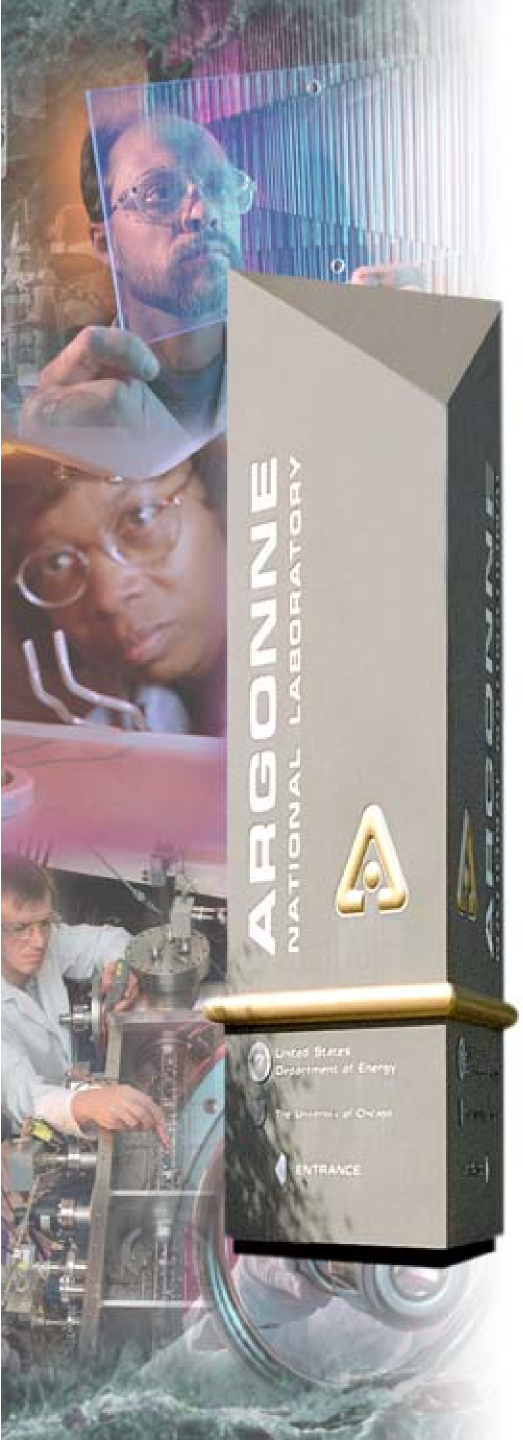

Bipolar Plate-Supported Solid Oxide Fuel Cell "TuffCell"

J. David Carter, Deborah Myers, and Romesh Kumar

Chemical Engineering Division

This presentation does not contain any proprietary or confidential information

Argonne National Laboratory

Office of Science
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Project Objectives

- **To develop an improved solid oxide fuel cell (SOFC) for Auxiliary Power Units and other portable applications**

- **Addressing the following SOFC issues:**
  - *Startup time*
  - *Durability to temperature cycling*
  - *Vibration and shock resistance*
  - *Materials and manufacturing cost*

Budget

- Total Project Funding, FY'02-FY'04: $550 K

- FY'04 Funding: $250 K

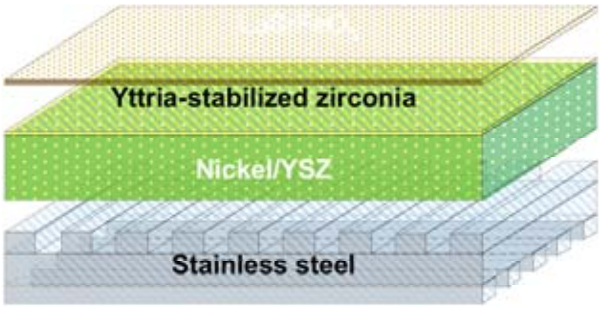
Technical Barriers and Targets

- **This project addresses DOE's Technical Barriers for Fuel Cell Components**
  - O: Stack Material and Manufacturing Cost
  - P: Durability
  - Q: Electrode Performance
  - R. Thermal and Water Management

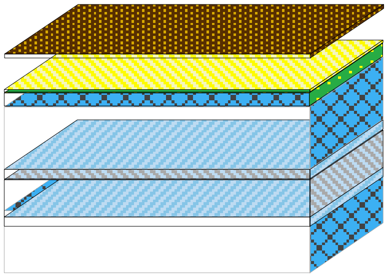
- **DOE's Technical Target is to develop a 3-5 kW_e Auxiliary Power Unit with the following attributes:**
  - Power Density: 150 W/kg and 170 W/L
  - Start-up time, cyclability, durability: 15-30 min, 500 cycles, 5,000 hours
  - Cost: $400/$kW_e$

Approaches

- Support cell on metallic bipolar plate to improve durability, cyclability, and shock-resistance
- Minimize thickness of expensive ceramic-containing layers (anode, electrolyte, and cathode)
- Fabricate cell components using powder metallurgy techniques
- Eliminate manufacturing steps to reduce cost
- Develop and test improved SOFC stacks

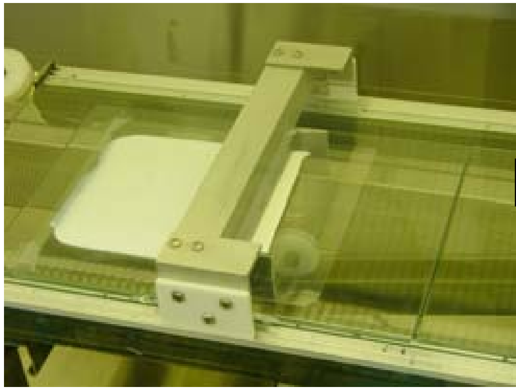


Anode-supported SOFC

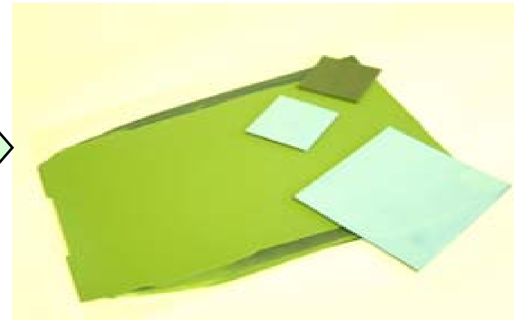


Metallic Bipolar Plate Supported SOFC

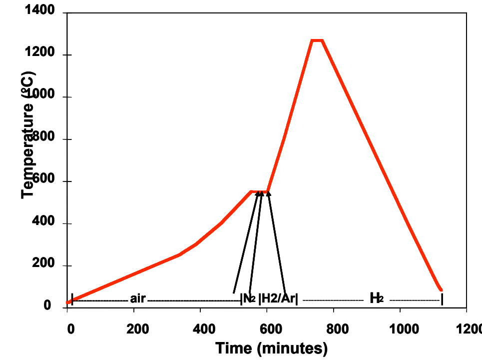
TuffCell design and fabrication procedure address SOFC shortcomings



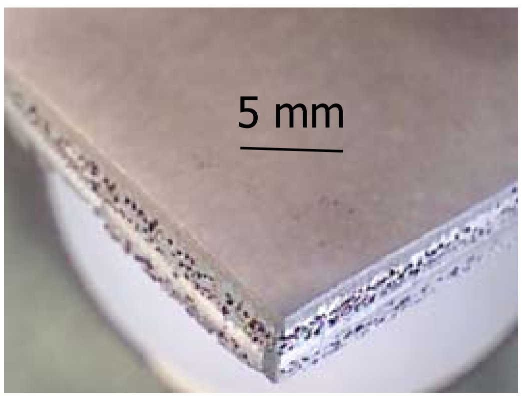
Tape cast cell layers (w/o cathode)



Laminate tapes together



Sinter laminate in one high-temperature procedure



Slurry-coat cathode to laminate and sinter *in situ*

- Thin layers of expensive ceramic materials
- Brittle ceramic components are bonded to tough metallic layers
- Single programmed high temperature process
- Single electrical contact plane between stack units

Safety

- **Internal safety reviews have been performed for all aspects of this project to address ESH issues**
  - Component fabrication
    - *All fabrication is performed in a hood to exhaust vapors of organic solvents and powders*
    - *Used organic solvents and powders are collected and disposed of through the laboratory's Waste Management Operations*
  - Cell sintering and cell/stack testing
    - *Performed in a hood equipped with hydrogen monitors that trigger automatic shut down of process/test*
- **Safety reviews are updated and renewed annually**

Project Timeline

10/01
Began

$

12/01
Achieved sintered laminate

2/02
TuffCell has 4x strength of anode-supported cell

4/02
OCV of 1.14 V
25 mW/cm_

8/02
Power max. of 104 mW/cm_

11/02
Power max. of >260 mW/cm_

11/03
Designed and fabricated stack test apparatus

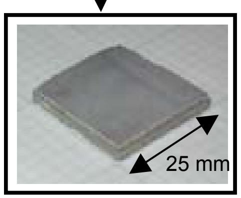
12/03
Fabricated edge sealant material
Designed and fabricated a two-cell stack

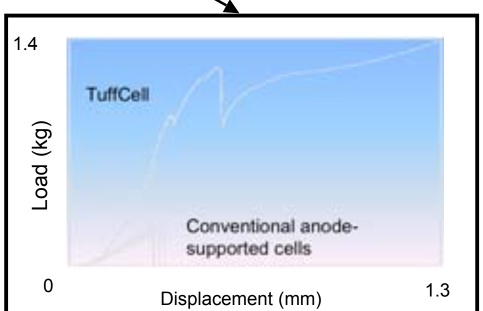
1/04
First stack test

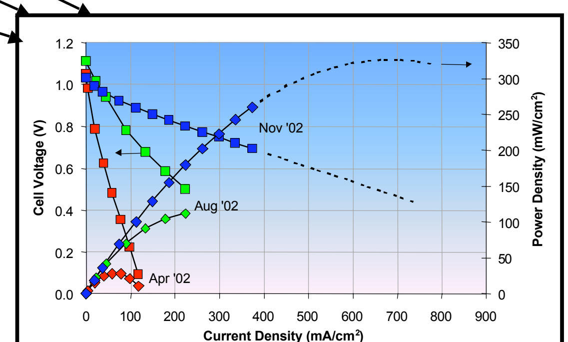
FY '02

FY '03

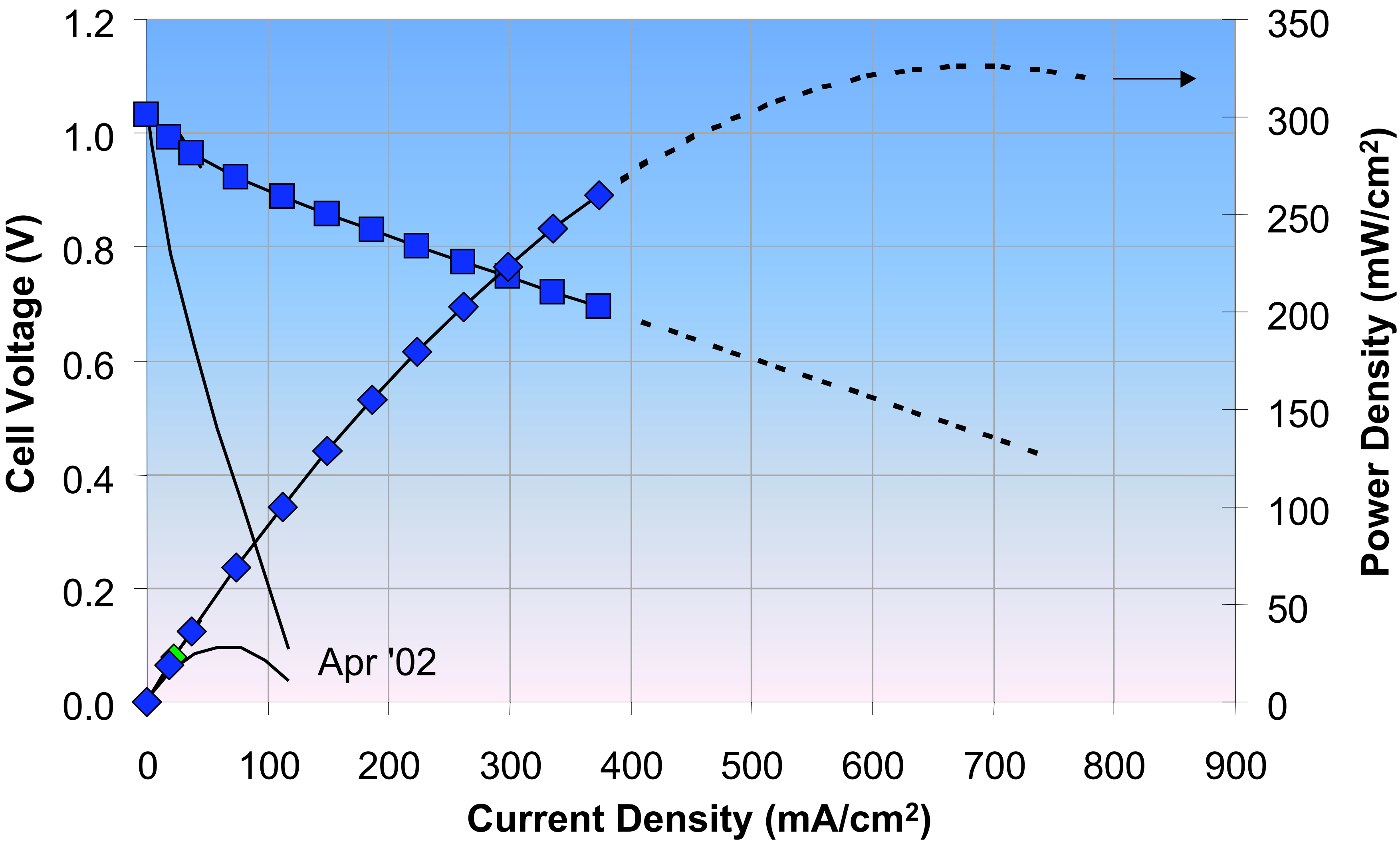
FY '04





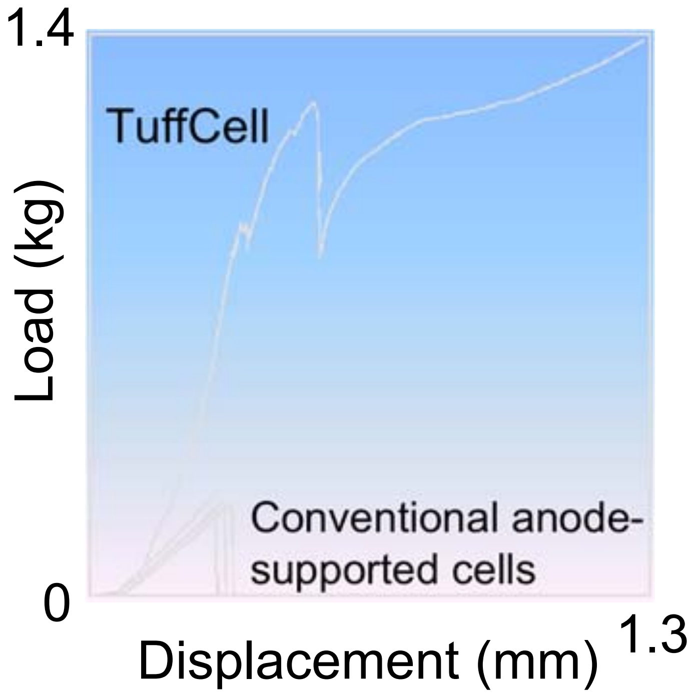


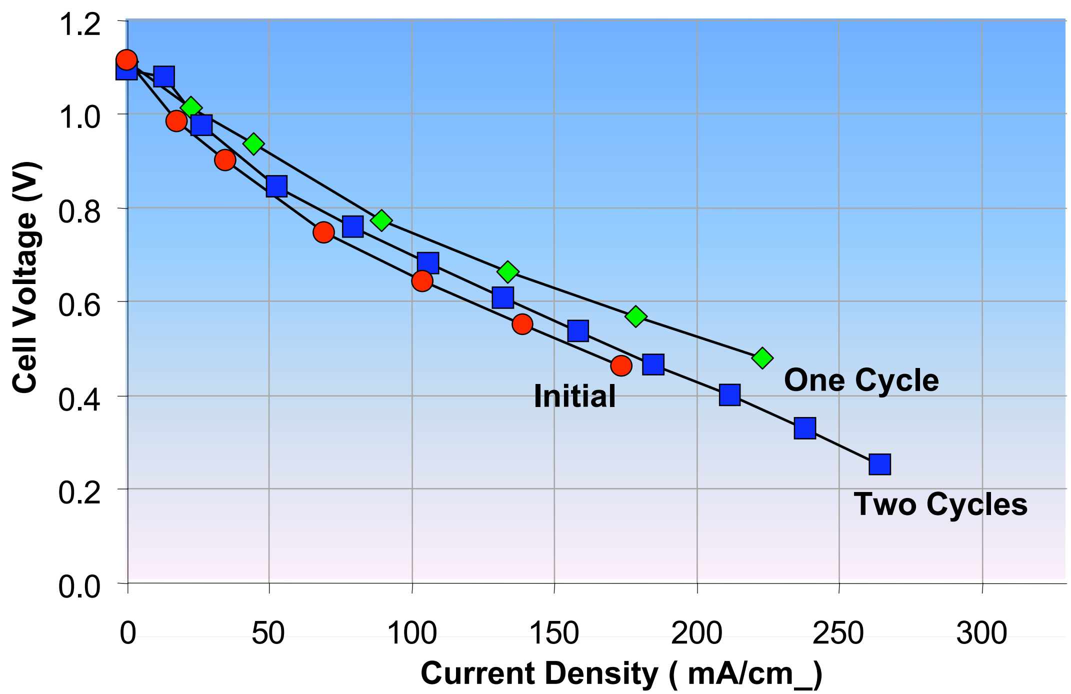
Current status of TuffCell's power density



TuffCell's superior mechanical properties, cyclability demonstrated

Physical tests:
- Impact test
- 4-point bend test
- Temperature cycling from RT to 800° C at ~10° C/min



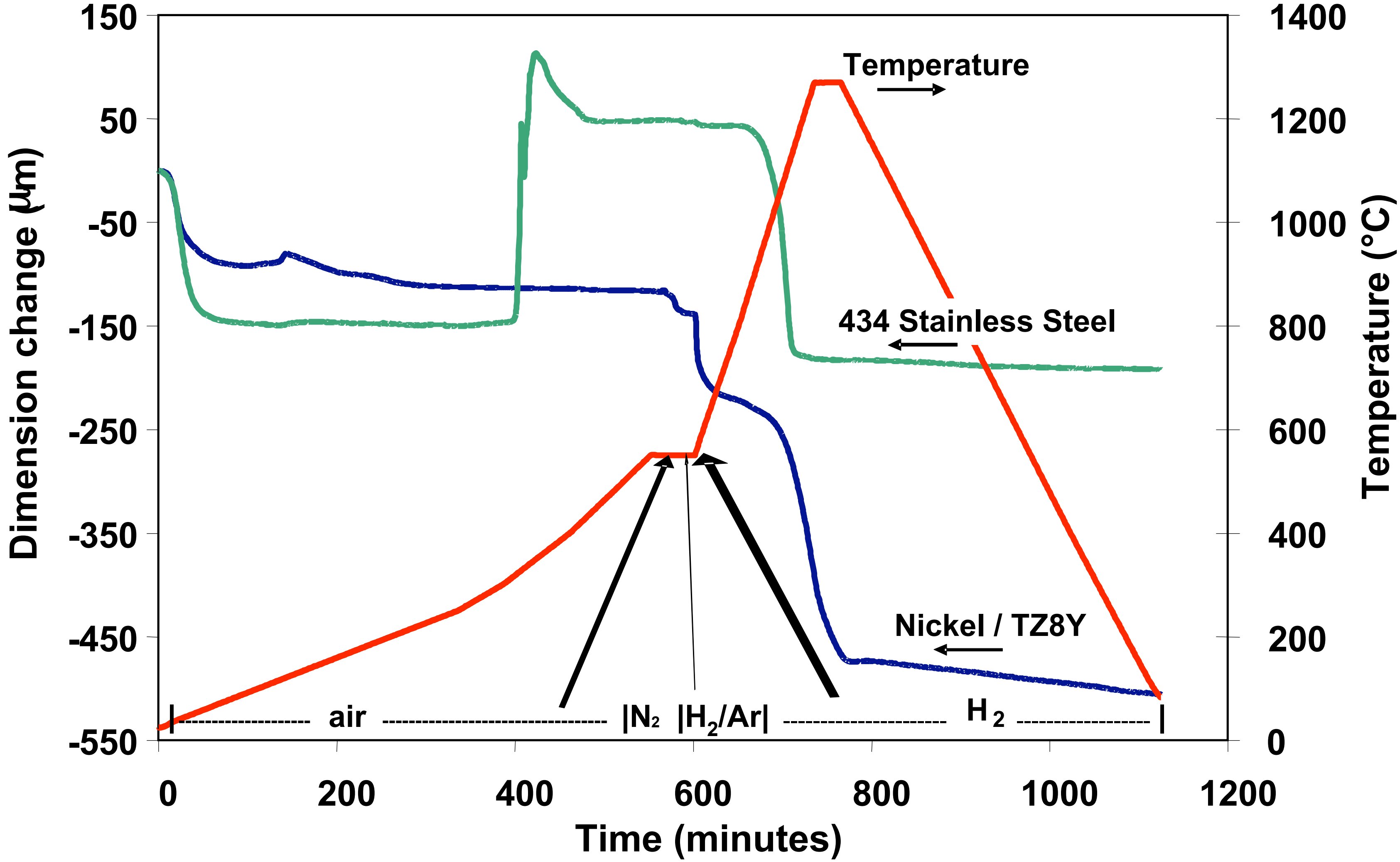


TuffCell stack development efforts

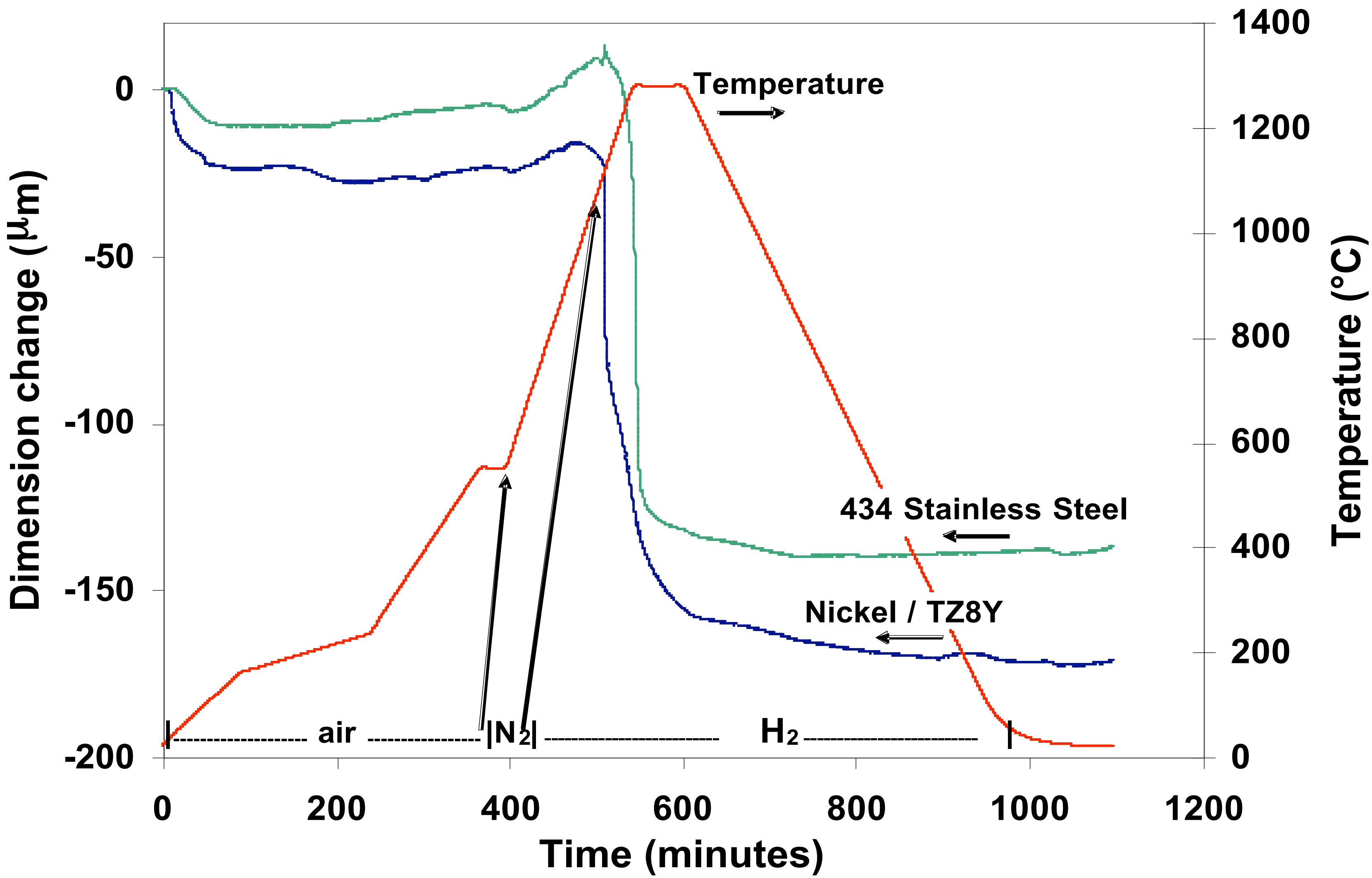
- **Feb. 2004 Milestone:**
  Test two-cell stack on simulated reformate/air

- **Stack test requires cell modifications/refinements**
  - Individual cell size scale-up from 1”x1” to 2”x2”
  - Gas impermeable bipolar plate
  - Edge sealing for gas manifolding
  - Corner sealing for gas manifolding
  - Coating of chromium-containing cathode flow field
  - Flat flow fields for good electrical contact between cells

Dilatometer study showed problem with bipolar plate binder burn-out

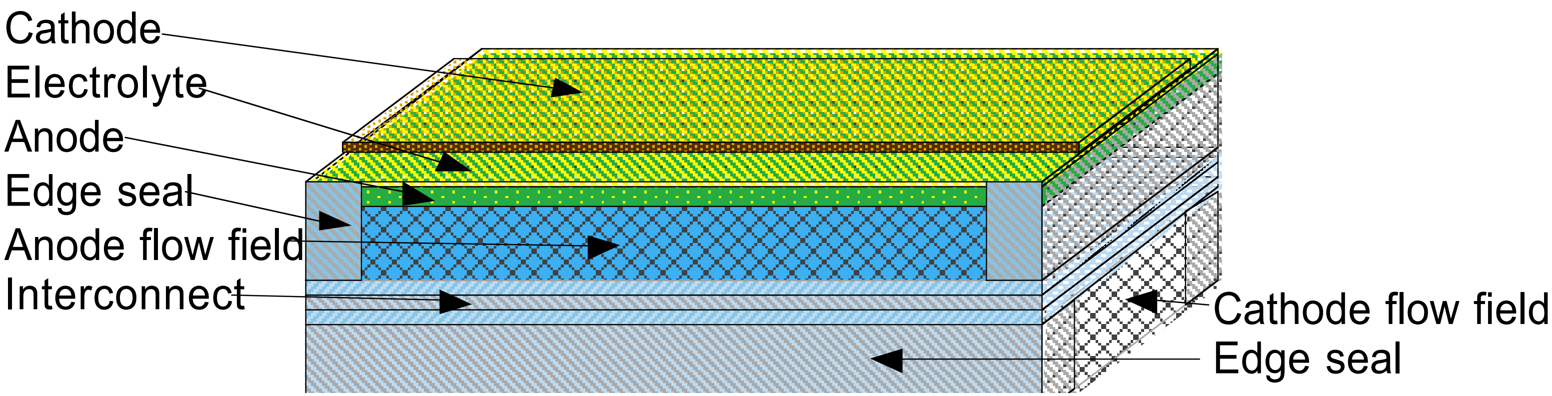


New binder solved problem of component expansion mismatch during high-temperature processing

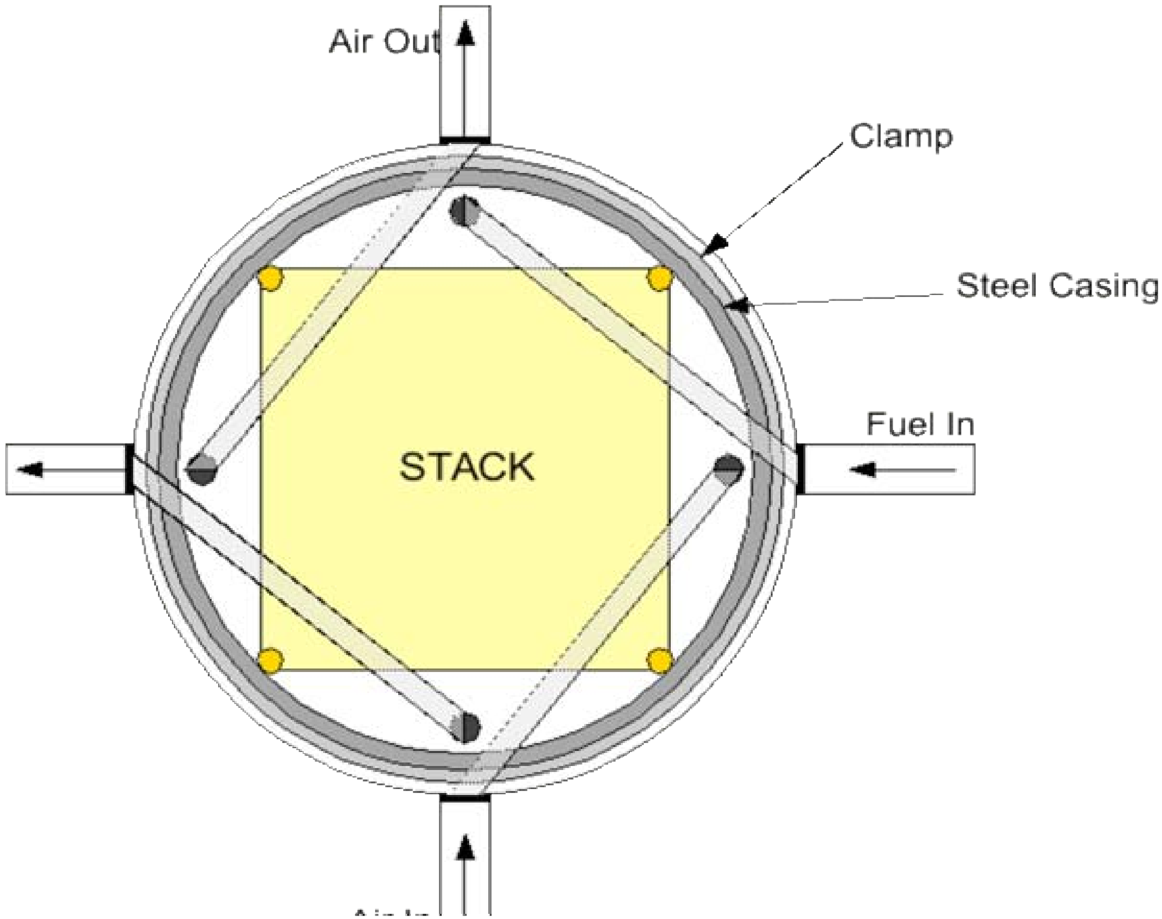


Cell fabrication for stack required development of edge sealing procedure

- **Metal slip composition was altered to allow metal to be injected into the edges of the flow field tape**



A novel and flexible stack test apparatus was designed and built



A two-cell stack (with edge sealing) was fabricated and tested at 800°C

Bipolar Plate
Cathode Flow Field

TuffCell repeat unit

Anode/Electrolyte/Cathode
Anode Flow Field
Bipolar Plate

Gold foil current collector

Results and lessons learned from stack test

- **A realistic open circuit potential was not achieved**
- **Corner gaskets leaked**
  - *Composition of gaskets will be altered to reduce porosity*
- **Metal flow fields caused a large pressure drop through the stack at 1/16-in thickness**
  - *Increased thickness to 1/8-in while minimizing weight increase by improving metal coating procedure*
- **Poor contact between adjacent cells**
  - *Metal flow fields will be ground flat before assembly of stack*

Progress vs. FY ’04 Milestones

- **Test two-cell stack on simulated reformate/air (2/04)**
  - Scaled single cell fabrication from 1x1 in size to 2x2
  - Designed and built stack test apparatus and developed internal manifolding procedure
  - Fabricated first two-cell TuffCell stack and tested it on hydrogen/air

- **Complete start-up time and cycle tests (6/04)**
  - Once stack sealing issues have been resolved, we will test start-up time and cycle tests

- **Obtain a single cell power density of >350 mW/cm_ (9/04)**
  - Improved single cell fabrication materials and procedure using dilatometer results. Current status: 260 mW/cm_

Interactions and Collaborations

- **Collaboration with Korea Advanced Institute of Science and Technology:**
  Professor Joongmyeon Bae

- **Samples will be provided to Motorola for evaluation (Non-disclosure agreement recently signed)**

- **Patent Application: US2003/0232230 A1**

Reviewers' comments from Berkeley meeting

- **Important to demonstrate a two-cell stack**
  - *Work-in-progress*

- **Estimate cost of TuffCell and where the opportunities are relative to the \$400/kW$_e$ target**
  - *Anode-supported SOFC Stack Materials: \$139/kW$_e$*
  - *TuffCell Stack Materials: \$85/kW$_e$*

- **May trade some performance for reliability**
  - *TuffCell should have improved performance due to elimination of resistive bond layers/interfaces*

Future Plans - FY'04 and Beyond

- **Continue to improve single cell and stack power densities to decrease size, weight, and cost**
  - Improve design and fabrication procedure
  - Investigate improved materials for metallic support, anode, and cathode

- **Demonstrate that TuffCell stacks can meet DOE Performance Technical Targets for APU application**
  - Test start-up time (goal: < 30 min.)
  - Temperature cycling tests (goal: > 500 cycles)
  - Investigate durability (goal: > 5,000 operating hours)

Acknowledgments

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